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54 Portable PCMCIA interface for a host computer.

57 A portable PCMCIA interface for a host computer having a system bus. In one embodiment, the host computer is a SPARC based computer having an SBus and running the UNIX operating system. The PCMCIA interface provides a user application with access to a PCMCIA card. In this embodiment, the PCMCIA interface includes software and hardware components. The software component includes a hardware-independent portion and a hardware-dependent portion. By implementing the software in a suitable high level language such as "C", the software can be easily ported to other hardware platforms by merely adapting the hardware-dependent portion. The hardware component includes an ASIC coupled between the system bus and a couple of PCMCIA sockets. In some embodiments, the hardware also includes a 5 volt to 12 volt DC-DC converter between the system bus and the PCMCIA sockets.

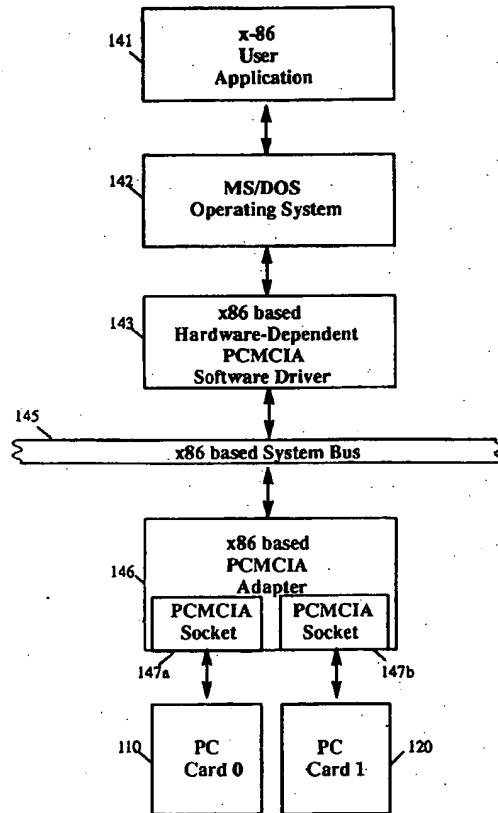


FIG. 2  
Prior Art

The present invention relates to an interface between a host computer and a peripheral device.

More particularly, the present invention relates to an interface between the host computer and a Personal Computer Memory Card International Association (PCMCIA) peripheral card.

Figure 1A is a block diagram showing the hardware components of a conventional non x86 based host computer, such as a scalable processor architecture (SPARC) host computer. (SPARC® is a registered trademark of SPARC International, Inc.) Host computer 10 includes a host central processor unit (CPU) 20, a memory bus (M-bus) 35, a host memory 30, a host bus controller 50, a standardized host system bus 55 and input/output (I/O) devices such as a monitor/keyboard/mouse 41 and a hard disk drive 42. System bus 55 interconnects and provides communication between CPU 20 and I/O devices 41, 42. In some host computers, system bus 55 is a SPARC based SBus.

Figure 1B illustrates the software components of the host computer of Figure 1A. A UNIX user application 31 is coupled to a UNIX operating system (O/S) 130 having a kernel 32 and hardware-dependent drivers 33, and system bus 55. (UNIX® is a registered trademark of UNIX System Laboratories, Inc., a wholly-owned subsidiary of Novell, Inc.) System bus 55 is coupled to I/O devices 41, 42. Typically, when host computer 10 is first initialized, UNIX O/S 130 is loaded into host memory 30 and remains resident until computer 10 is powered down. Consequently, I/O device drivers 33 corresponding to I/O devices 41, 42 are loaded and user application 31 has access to I/O devices 41, 42 by making the appropriate calls to kernel 32 which communicates the access via device drivers 33, system bus 55 to I/O devices 41, 42.

The increase in the processing power of computers such as host computer 10 has caused a corresponding increase in the complexity of user applications such as application 31. As a result, there is an increasing need for additional memory, mass storage and communication devices, the most convenient form being an external device coupled to system bus 55. Typically, adding external memory or mass storage devices to host computer 10 involves the insertion of an adapter in the form of a printed circuit board (PCB) into an available system bus slot located inside the housing of computer 10. When inserted into the system bus slot, the PCB is electrically coupled to system bus 55 and the adapter is therefore capable of communicating with host CPU 20. Hence, the maximum number of external devices that can be coupled to host computer 10 is limited by the total number of system bus slots available within computer 10. Further, a typical non-technical user is not trained to insert or remove PCBs, and a trained technician or service person is required to make such an upgrade or change.

Meanwhile, in a different hardware arena of computers based on Intel's x86 family of microprocessors, such as the IBM personal computer, a PCMCIA specification was developed to promote both compatibility and interoperability for adding external devices. (Intel® is a registered trademark of Intel Corporation and IBM® is a registered trademark of International Business Machines Corporation.) Typically a PCMCIA adapter provides standardized PCMCIA socket(s) for plugging in PCMCIA cards (PC cards), and is controlled by associated interface software running on the host computer. Hence, it is now possible for an end user to easily insert and interchange a wide variety of external peripheral and memory devices implemented in the PC card format into an x86-based host computer on demand.

Initially, the x86-based PCMCIA interface was designed for relatively fast random access memory (RAM) cards and hence the specified read/write protocol between the adapter and the x86-based host computer is similar to that necessary for a memory-type access operation. PC cards with memory include RAM PC cards and hard disk drive PC cards. More recently, the PCMCIA specification was extended to accommodate PC cards requiring I/O type data access protocol, such as FAX modem cards.

Figure 2 is a block diagram showing both the software and hardware components of one such prior art x86-based host computer having a PCMCIA interface specifically designed for an x86-based computer system bus, such as an ISA or VESA bus. The software component includes user application 141, Microsoft's disk operating system (DOS) 142 and an x86-based hardware-dependent PCMCIA software driver 143. (Microsoft® is a registered trademark of Microsoft Corporation.) The hardware component includes an x86-based system bus 145 and an x86-based PCMCIA adapter 146 having a pair of PCMCIA sockets 147a, 147b for housing a corresponding pair of PC cards 110, 120. Two examples of prior art integrated circuits (ICs) for the x86 based PCMCIA adapter are Intel's 82365SL PC card interface controller and Cirrus Logic's CL-PD6710/20.

User application 141 accesses PC card 110 or 120 by first making a standardized system call to DOS 142. Next, DOS 142 makes the appropriate PCMCIA call to x86-based PCMCIA software driver 143 in order to communicate the access across x86-based system bus 145 to PCMCIA adapter 146. Upon receiving the access request over bus 145, adapter 146 translates the system bus signals into standardized PCMCIA signals for PC card 110 or 120.

One problem associated with the conventional PCMCIA interface is that the PCMCIA specification was originally developed for computers based on Intel's x86 family of microprocessors running operating systems such as DOS, MS-Windows or OS/2. (MS-Windows® is a trademark of Microsoft Corpora-

tion.) Consequently, the PCMCIA specification was optimized for software drivers which are coded in whole or part in an x86 assembler language which cannot be easily ported to non-x86-based computer systems.

Another problem with most conventional operating systems, such as UNIX and DOS, is that they are not designed to arbitrarily allow hardware devices to be connected and disconnected at random while the host computer is operating. Traditionally, at system boot time each device driver is polled once to determine if the corresponding hardware device is present. If the device has been disconnected or is non-functional, the device driver is either unloaded from the host computer memory, or if left in the memory, the driver is never used. This particular conventional operating system characteristic prevents PC cards from being safely "hot-plugged", i.e., the practice of inserting or removing PC cards from a PCMCIA socket while the host computer is operating.

Hence, there is a need for a portable PCMCIA interface which fully supports the software and hardware PCMCIA specification and is independent of the host computer's bus architecture, processor or operating system. Such a portable PCMCIA interface will enable other host computers based on hardware architectures such as SPARC, and operating systems such as UNIX, to utilize the growing bank of standardized PC cards, while fully supporting the PCMCIA features such as hot-plugging.

## SUMMARY OF THE INVENTION

The present invention provides a portable PCMCIA interface operational on many host computer architectures to couple a user application to a PC card.

In one embodiment, the user application runs in a host computer having a host system bus. The PCMCIA interface includes both software and hardware components. The PCMCIA interface software includes a hardware-independent portion and a hardware-dependent portion, with a defined external interface between the user application and the hardware-independent portion. The external PCMCIA software interface provides PCMCIA Card Services and Socket Services to the user application in a manner transparent to the underlying hardware, e.g., the PC card. In addition, there is a defined internal interface between the hardware-independent and hardware-dependent portions of the PCMCIA interface software, enabling the entire PCMCIA interface to be easily ported to other host computers by merely adapting the hardware-dependent portion.

The PCMCIA interface hardware includes a PCMCIA adapter coupled to the system bus, the adapter having at least one PCMCIA socket for accommodating the PC card. The user application ini-

tiates all data transfers to and from the PC card, as dictated by the PCMCIA specification. The host system bus compatible PCMCIA adapter supports 8 bit, 16 bit and 32 bit data transfers to and from attribute memory space, common memory space and I/O space of the PC card.

In some embodiments, the addition of power switching circuitry between the system bus power supply and PCMCIA socket(s) of the PCMCIA adapter enables the PC card(s) to be safely inserted in and removed from the PCMCIA socket(s) without the need for powering down the host computer. An optional 5 volt to 12 volt DC-DC converter provides additional compatibility for PC cards requiring a 12 volt supply.

The PCMCIA interface of the present invention has a number of advantages over the prior art. By providing a defined internal interface between the hardware-independent and hardware-dependent portions of the PCMCIA interface software, the specific characteristics of the system bus, the adapter and the PC card become transparent to the user application software running on the host computer. In addition, by implementing the software in a high level programming language, the entire PCMCIA interface software can be ported to other host computers having different operating systems and hardware architectures by merely adapting the hardware-dependent portion. Accordingly, the PCMCIA interface of the present invention provides a hardware and software solution which can be easily ported to other host computers.

The present invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1A illustrates the hardware components of a conventional SPARC host computer.

Figure 1B illustrates the software components of the host computer of Figure 1A.

Figure 2 illustrates a prior art x86-based host computer having a PCMCIA interface.

Figure 3A illustrates a PCMCIA interface coupled to a host computer in accordance with one embodiment of the present invention.

Figure 3B illustrates the PCMCIA interface software running on the host computer of Figure 3A.

Figure 4 is a block diagram showing the PCMCIA interface software in greater detail.

Figure 5 is a flow chart illustrating an access of a PC card by a user application running on the host computer.

Figure 6 illustrates a PCMCIA hardware adapter of the present invention.

Figure 7 is an address map showing the SBus address space of the host computer allocated to PC cards.

Figure 8 are two timing diagrams illustrating conventional PCMCIA read and write access cycles.

Figure 9 illustrates a PC card read access of an attribute or common memory space.

Figure 10 illustrates a PC card read access of an attribute or common memory space with the WAIT feature.

Figure 11 illustrates a PC card write access of an attribute or common memory space.

Figure 12 illustrates a PC card write access of an attribute or common memory space with the WAIT feature.

Figure 13 illustrates a PC card write access of an I/O space with byte sizing, but without the WAIT feature.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

In Figure 3A, a scalable processor architecture (SPARC) based host computer coupled to a PCMCIA adapter of the present invention is shown. For more information on the SPARC computer architecture, see the SPARC Architecture Manual, Version 8, 1992, available from SPARC International, Menlo Park, California. As the operation of SPARC-based host computer 10 is well known, a detailed description is not provided herein.

In accordance with one embodiment of the invention, host computer 10 is coupled to a PCMCIA adapter 100 via system bus 55. Adapter 100 has a pair of PCMCIA sockets 107, 108 for housing a corresponding pair of PC cards 110, 120. PC cards 110, 120 are inserted into adapter 100 via a corresponding pair of 68-pin connectors located within PCMCIA sockets 107, 108.

It should be noted that adapter 100 may assume a variety of physical configurations. For example, in one embodiment for a desktop computer, adapter 100 includes an application specific integrated circuit (ASIC) mounted on a peripheral printed circuit board (PCB), with the PCB occupying a physical slot in system bus 55. An electrical cable interconnects the ASIC to PCMCIA sockets 107, 108. In another embodiment for a palm-top computer, adapter 100 includes an ASIC which resides, together with CPU 20 on a main PCB. An electrical cable interconnects the ASIC to PCMCIA sockets 107, 108 which are attached to the palm-top computer housing. Alternatively, PCMCIA sockets 107, 108 are mounted together with the ASIC and CPU 20 on the main PCB of the desktop or lap top computer, thereby eliminating the need for an interconnecting electrical cable. Other embodiments and variations are also possible and will be apparent to one skilled in the art in view of this disclosure.

For the purpose of describing the operation of a PCMCIA interface software driver running on host computer 10 and controlling PCMCIA adapter 100, reference is made mainly to PC card 110 and its associated hardware and software drivers. Since both PC Cards 110, 120 are electrically and physically cou-

pled to PCMCIA sockets 107, 108, respectively, the description of the operation of the software driver and adapter 100 with respect to first PC card 110 is equally applicable to second PC card 120.

5 In this embodiment, as illustrated by the block diagram of Figure 3B, an UNIX operating system 135 which includes UNIX kernel 32 and device drivers 33, also includes a PCMCIA interface software driver 34. A UNIX compatible user application 31 accesses PC card 110 via PCMCIA interface software driver 34, system bus 55 and adapter 100. Software driver 34 includes a hardware-independent portion 34a and a hardware-dependent portion 34b.

15 Interface software driver 34 is coded in a suitable high level programming language, such as the "C" language, enabling source code of driver 34 to be easily ported to other host computer platforms by merely making source code changes to hardware-dependent portion 34b and recompiling driver 34. Examples of other possible host computer configurations include the UNIX operating system on an x86 microprocessor based computer. Other variations and modifications of host computer platforms are apparent to one skilled in the art.

20 Figure 4 is a block diagram showing PCMCIA interface software driver 34 in greater detail. Hardware-independent portion 34a includes a pair of PC card drivers 260, 270, a PCMCIA nexus driver 210, an event manager 230 and a Card Services layer 220. Hardware-dependent portion 34b comprises a system bus compatible PCMCIA adapter driver 250 for controlling adapter 100. By clearly defining an internal interface 215 between hardware-independent nexus driver 210 and hardware-dependent system bus compatible adapter driver 250, in accordance with one aspect of the invention, the entire PCMCIA interface can advantageously be ported to different host computer platforms by merely adapting hardware-dependent portion 34b of interface software driver 34.

25 Before user application 31 can begin accessing PC card 110, PCMCIA interface software driver 34 must first be loaded into host memory 30. Loading of the various portions of software driver 34 is accomplished during initialization of host computer 10. When PCMCIA nexus driver 210 is first loaded, nexus driver 210 searches through a list of all possible adapter drivers stored in a configuration file, and attempts to load each adapter driver into the configuration file. For each successful load of a specific adapter driver, e.g., adapter driver 250, nexus driver 210 locates a corresponding driver apparatus structure, e.g. structure 251, associated with each adapter, e.g., adapter driver 250. Adapter driver 250 then saves a pointer to the corresponding driver apparatus structure 251.

30 Next, PCMCIA nexus driver 210 queries PCMCIA adapter driver 250 to obtain its basic adapter characteristics and adds PCMCIA sockets 107, 108 to the

list of available logical sockets. Nexus driver 210 then exports the logical socket list to Card Services layer 220. Consequently, Card Services layer 220 has access to a hardware-independent software interface 215 located between nexus driver 210 and adapter driver 250, enabling Card Services layer 220 to control and manage the resources of adapter 100 and PCMCIA socket 107 in a hardware-independent manner. Nexus driver 210 also exports the same logical socket list to adapter driver 250 thereby establishing a one-to-one logical socket communication channel between Card Services layer 220 and adapter driver 250.

Card Services layer 220 also includes a Card Information Structure (CIS) interpreter 220a which enables PC card 110 to be self identifying independent of the host computer architecture and operating system, by requiring PC card 110 to maintain self-identifying information in its CIS. The CIS is stored in an Attribute Memory space of PC card 110 and is made up of a singly-linked list of variable-length elements called tuples. Interpreter 220a is a tuple parser which is responsible for processing all of the tuple information. As such, PC card driver 260 does not need any tuple parsing code.

In this embodiment, each tuple is one byte in length, with up to 256 distinct tuples stored in the CIS of PC card 110. When a tuple is parsed and recognized by interpreter 220a, interpreter 220a causes the tuple data from PC card 110 to be copied into a tuple entry in an interpreter linked list 220b. Conversely, when interpreter 220a does not recognize the tuple, a flag is set indicating that the tuple was not recognized and that tuple data from PC card 110 should not be copied into a tuple entry in interpreter linked list 220b. Upon the successful parsing of the CIS of PC card 110, linked list 220b contains the configuration parameters of PC card 110, e.g., type of PC card, memory capacity and access speed. Subsequently, Card Services layer 220 uses linked list 220b for processing card service requests from PC card driver 260.

In some embodiments, PCMCIA nexus driver 210 does not export its private interface 215 with adapter driver 250 to PC card driver 260. Interface 225 between Card Services layer 220 and PCMCIA nexus driver 210 is also private, e.g., PC card driver 260 does not make direct calls to PCMCIA nexus driver 210. Instead, whenever user application 31 accesses PC card 110, all calls to PC card driver 260 destined for PCMCIA nexus driver 210 are serviced through Card Services layer 220. As such, Card Services layer 220 provides PC card driver 260 a single entry point with a variable argument list based on the function requested.

Next, in order to support a PCMCIA specified event callback feature, event manager 230 is loaded as a separate STREAMS, enabling nexus driver 210

to communicate PCMCIA events, such as PC card insertion/removal (hot-plugging), to user application 31. (STREAMS is a UNIX full-duplex connection between a process and a device driver). Hence, nexus driver 210 is provided an efficient event callback mechanism to user application 31, with event manager 230 observing the events and managing both adapter 100 and PC card 110 via adapter driver 250. Event manager 230 is an efficient solution because the number of PC cards available make it unwieldy and inefficient for user application 31 to poll for every possible PCMCIA card. More importantly, event manager 230 typically provides the sole mechanism (generally unsupported by UNIX) for implementing the PCMCIA specified channel for unsolicited feedback to user application 31:

For example, when PC card 110 has been successfully inserted into PCMCIA socket 107, nexus driver 210 receives a "card insertion" event notification from adapter driver 250, enabling nexus driver 210 to keep track of which type of PC card is present in socket 107. Subsequently, a corresponding PC card driver, e.g., driver 260, is loaded and nexus driver 210 updates the corresponding driver apparatus structure, e.g., structure 251, thereby forming an association between PCMCIA socket 107 and PC card 110. A discussion of the PCMCIA interface hardware for supporting this event callback feature is included in a detailed hardware description of adapter 100 below.

Once the loading and initialization of PCMCIA interface software driver 34 are completed, user application 31 has access to adapter 100 and PC card 110. Figure 5 is a flow chart illustrating an access of PC card 110 by user application 31 running on host computer 10 in accordance with one embodiment of the invention.

First, user application 31 makes an external hardware-independent PCMCIA call to PC card driver 260. Card driver 260 responds by requesting an appropriate card service from Card Services 220. Card Services 220 is responsible for processing all card services requests from PC card driver 260 and making the appropriate calls into PCMCIA nexus driver 210. PC card driver 260 provides Card Services 220 with a pointer to PC card driver's device information pointer (DIP) thereby uniquely identifying PC card 110 and providing a path to PC card driver 260's parent process, i.e., nexus driver 210. Card Services layer 220 then uses the DIP to locate and to make the appropriate calls into nexus driver 210. Such calls include adapter hardware configuration requests destined for socket services provided by adapter driver 250.

In response to the appropriate calls from Card Services layer 220, nexus driver 210 generates corresponding internal hardware-independent software calls to PCMCIA adapter driver 250. (For additional in-

formation on PC Card Services, please refer to Appendix A, which is incorporated herein.) Hardware-dependent adapter driver 250 then converts the internal software calls into appropriate system bus signals for adapter 100. Adapter 100 in turn generates the appropriate PCMCIA card signals for PC card 110 located in PCMCIA socket 107.

In sum, user application 31 initiates data accesses with PC card 110 by communicating the request in the form of a hardware-independent external PCMCIA call to PCMCIA interface software driver 34. In turn, software driver 34, resident on host memory 30, receives the external PCMCIA call and causes the appropriate-dependent adapter specific signals to be asserted on system bus 55. Hence, having described the operation and services provided by the various portions of interface software driver 34 in converting an access request from user application 31 into the appropriate system bus signals, the operation of the PCMCIA interface hardware, i.e., adapter 100 and PC card 110 is now described in detail.

In one embodiment as illustrated by Figure 6, PCMCIA adapter 100 includes an application specific IC (ASIC) 100a having a host bus interface buffer 101, an adapter core logic 102, and a card interface buffer 103. Adapter 100 also includes a power switch 105, a PROM 106, and a pair of PCMCIA sockets 107, 108. PROM 106 is an open boot PROM (OBP) which provides standard boot ROM functionality for host computer 10.

Figure 7 is an address map showing three megabytes of the system bus address space in host memory 30 allocated to each of PC cards 110, 120, i.e., a six megabytes of address space is dedicated to PC cards 110, 120.

In this embodiment, address space 0 to FFFFFh and 3FFFFFFh to 4FFFFFFh of memory 30, are reserved for accessing PROM 106, and the content of control and status registers (CSRs) 102a, respectively. The PCMCIA specification also supports up to 64 megabytes each for attribute memory, common memory and I/O memory space. However, in the described embodiment of PC card 110 only one megabyte of system bus address space each is reserved for attribute memory, common memory and I/O address space. As such, address mapping is required for transposing the system bus address space within specified PCMCIA address space. The address map for the 8 megabyte address space of adapter 100 is stored in PROM 106.

CSRs 102a are used to store parameters for configuring adapter 100 to operate with various type of PC cards. In addition, CSRs 102a also contain the address offset tables necessary for mapping each of the

one megabyte system bus address spaces within each of the 64 megabyte PC card address space. These address offset table values can be modified by host computer 10 to suit a particular PC card, e.g., a FAX modem card, a RAM memory card, or a Winchester disk drive card. Configuration parameters stored in CSRs 102a include the data access speed of PC card 110 which can vary a great deal depending on the card function, ranging from a relatively slow modem card to a relatively fast RAM card.

Figure 8 shows two basic timing diagrams illustrating conventional PCMCIA read and write access cycles on system bus 55 in response to read and write accesses of PC card 110 by user application 31. Note that data transfers are initiated by user application 31 as defined by the PCMCIA specification Version 2.1. For example, in response to a read access of PC card 110, adapter 100 asserts card address lines ADDR and card enable line CE\* of PCMCIA socket 107. Adapter 100 then asserts the output enable signal OE\*, indicating a read access of PC card 110 at the location indicated by card address lines ADDR. After a specific period of time (i.e., PC card read access time), PC card 110 drives the requested data onto card data lines DATA. Similarly, in response to a write access of PC card 110, adapter 100 asserts card data lines DATA, card address lines ADDR and card enable line CE\*, followed by the assertion of card write enable line WE.

In accordance with one embodiment of the invention, adapter 100 supports byte, halfword (16-bit) and word (32-bit) data accesses of PC card 110. Since PCMCIA socket 107 can only support 16-bit data transfers, any sizing is performed external to PC card 110. Although the described embodiment of adapter 100 does not perform any data packing (i.e., adapter 100 does not generate multiple read accesses to card 110 in response to a single system bus read request), one skilled in the art will be able to extend the principles of operation to other embodiments of adapter 100 that supports data accesses of word lengths greater than 16-bits without the need for external sizing by host computer 10.

In addition, when an access is initiated at an attribute memory space or at an I/O address space of card 110, card memory select line C0\_REG\* is asserted low. Conversely, when an access is initiated at a common memory space, card memory select line C0\_REG\* is asserted high.

Referring to the timing diagram of Figure 9, a byte wide read initiated by computer 10 via adapter 100 of an attribute or common memory space on PC card 110 is illustrated. First, a base address value BASE stored in a corresponding Window Control Register of

\*Signal is active low.

control and status register 102a and the offset address value on system bus address lines SB\_PA are presented on card address lines C0\_A thereby mapping the system bus address into a PC card address. Next, a card output enable line C0\_CE\* is asserted low. L+1 clock cycles later, L being the Command\_Strobe\_Delay value CMDDLY stored in the Window Control Register, a card output enable line C0\_OE\* (shown as C0\_RDCMD\* in Figure 9) is asserted low. The selected PC card, i.e., PC card 110, then retrieves the requested memory data byte internally and presents the data value onto card data lines C0\_D.

After another M+1 clock cycles, where M is a Command\_Strobe\_Length value CMDLNG stored in the Window Control Register, the data byte value on card data lines C0\_D is latched by adapter 100 and card output enable line C0\_RDCMD\* is de-asserted. One clock later, card output enable line C0\_CE\* is de-asserted. Finally, adapter 100 asserts a byte "ACK" on system bus line SB\_ACK\* for host computer 10, driving the latched data byte onto system bus data lines SB\_DATA another clock cycle later, thereby completing the byte wide read cycle.

A halfword wide attribute or common memory read of PC card 110 is as follows. First, the BASE value in the Window Control Register is applied onto card address lines C0\_A, the offset address value on system bus address lines SB\_PA is applied onto card address lines C0\_A, and card enable line C0\_CE\* is asserted low. L+1 clock cycles later, card output enable line C0\_OE\* (shown as C0\_RDCMD\* in Figure 9) is asserted low. Selected PC card 110 then presents the corresponding memory data bytes onto card data lines C0\_D. After M+1 clock cycles, the valid data bytes on card data lines C0\_D are latched into adapter 100 and card enable line C0\_OE\* (see C0\_RDCMD\*) is then de-asserted. One clock cycle later, card enable line C0\_CE\* is de-asserted. Adapter 100 asserts a halfword ACK onto system bus line SB\_ACK\* and drives the latched data byte-swapped onto system bus data lines SB\_DATA, thereby completing the halfword read cycle.

A word wide attribute or common memory read of PC card 110 is similar to the halfword read access up to and including the assertion of the halfword ACK back to host computer 10. The halfword ACK on system bus 55 informs host computer 10 that the word read requires sizing. As such, computer 10 must initiate another access via system bus 55 to read the other halfword of the desired word of data. The second read cycle of the second halfword occurs in the same manner with the exception that the value on system bus address line SB\_PA[1] and also card ad-

dress line C0\_A[1] are now both "1" instead of "0", so that the appropriate next halfword of data is fetched.

As discussed earlier, the PCMCIA specification was originally developed for external RAM memory cards. However, as other slower storage mediums, e.g., hard disk drives, were physically shrunk to fit the PCMCIA form factors, it became necessary to enhance the PCMCIA specification to support another mode of operation, i.e., accessing PC card 110 using a "WAIT" feature. In this embodiment, the WAIT feature enables adapter 100 to allow a slow PC card 100 to delay responding to an access by assert a card wait signal C0\_WAIT\*, as illustrated by Figure 10.

When host computer 10 initiates a read access to PC card 110 which utilizes card wait line C0\_WAIT\*, (a wait\_request bit WAITREQ is enabled in the Window Control Register), the BASE value and the offset address value on system bus address lines SB\_PA are applied onto card address lines C0\_A, and card enable line C0\_CE\* is asserted low. L+1 clock cycles later, card output enable line C0\_OE\* (shown as C0\_RDCMD\* in Figure 10) is asserted low.

M+N+2 clock cycles later, N equal to a Wait\_Delay value WAITDLY in the Window Control Register, adapter 100 samples card wait line C0\_WAIT\*. If card wait line C0\_WAIT\* is asserted PC card 110 requires a delay in the completion of the memory access. The PCMCIA specification permits card wait line C0\_WAIT\* to be asserted for a maximum of 12 microseconds. Since the rising edge of card wait line C0\_WAIT\* is asynchronous with respect a system clock of host computer 10, when PC card 110 de-asserts card wait line C0\_WAIT\*, adapter 100 has to synchronize incoming card wait line C0\_WAIT\*.

Next, PC card 110 asserts the requested memory data bytes onto card data lines C0\_D before de-asserting card wait line C0\_WAIT\*. Adapter 100 latches the data and de-asserts card output enable line C0\_OE\* (see C0\_RDCMD\* of Figure 10). One clock cycle later, card enable line C0\_CE\* is de-asserted. Finally, adapter 100 asserts an "ACK" on system bus line SB\_ACK\* and a clock cycle later, presents the latched data onto system bus data lines SB\_DATA.

A non-wait byte I/O read access of PC card 110 is similar to that of the byte read of an attribute or common memory described above with the exception that a card I/O ready line C0\_IORD\* (shown as C0\_RDCMD\* in Figure 10) is asserted low instead of card output enable line C0\_OE\*. Similarly, a halfword I/O read access begins as in the halfword read of attribute or common memory with the exception that card line C0\_IORD\* (see C0\_RDCMD\*) is used in-

\*Signal is active low.

\*Signal is active low.

\*Signal is active low.

stead of card enable line C0\_OE\*.

If PC card 110 is capable of performing a 16-bit I/O access, card 110 asserts a card I/O\_is\_16\_bit line IOIS16 (not shown) low during the read access, and both bytes of data are presented onto card data lines C0\_D, i.e., all 16 data bit lines are valid. Adapter 100 then generates a halfword ACK to host computer 10 via system bus line SB\_ACK\* and presents the latched data byte-swapped onto system bus data lines SB\_DATA a clock cycle later.

Conversely, if PC card 110 is only capable of byte sized I/O read access, card 110 does not assert card line IOIS16\* low during the read access, and only the data byte presented on the responding 8 bits of card data lines C0\_D are valid. Next, adapter 100 asserts a byte ACK to host computer 10 via system bus line SB\_ACK\* thereby indicating that the halfword I/O access requires sizing. Host computer 10 then initiates another I/O access on system bus 55 to read the second byte in order to complete the halfword I/O access.

An I/O read of PC card 110 with the WAIT feature is also similar to the read access of an attribute or common memory with the WAIT feature, with the exception that card I/O ready line C0\_IORD\* (shown as C0\_RDCMD\* in Figure 10) is asserted low instead of card line C0\_OE\*. The PCMCIA specification permits a maximum of 12 microseconds delay between the beginning and end of a read access. However, PC card 110 can delay completion of the read access beyond the 12 microseconds by using card line C0\_WAIT\*, requiring adapter 100 to support split reads on system bus 55. Once a read is initiated by host computer 10 on system bus 55, a rerun ACK is asserted by adapter 100 if a time out occurs while card wait line C0\_WAIT\* is asserted by PC card 110. The split read access is completed during a subsequent read retry by host computer 10 on system bus 55. Next, PC card 110 de-asserts card wait line C0\_WAIT\* with the read data is presented system bus data lines SB\_DATA.

Conversely, if PC card 110 asserts but fails to de-assert card wait line C0\_WAIT\* within the 20 microseconds during a read access cycle, adapter 100 terminates the read access cycle and generates an interrupt on system bus 55. The interrupt signals to host computer 10 that a WAIT time-out has occurred.

In accordance with this embodiment of the invention, adapter 100 also supports non-WAIT byte, half-word and word data write accesses on PC card 110, as illustrated in the timing diagram of Figure 11. Adapter 100 has a 16-bit wide data interface with system bus 55 and with external sizing performed by host computer 10 for word-size write accesses using halfword ACKs. As discussed above when computer 10

initiates a write access at an attribute or common memory or I/O address space, card select line C0\_REG\* is asserted low.

When a byte write of PC card 110 attribute or common memory is initiated by computer 10, the BASE address value and the offset address value from system bus address lines SB\_PA are presented onto card address lines C0\_A, the data value on system bus data lines SB\_DATA is driven onto card data lines C0\_D, and card output enable line C0\_CE\* is asserted low. Next, adapter 100 asserts a byte ACK thereby terminating the write cycle on system bus 55. L+1 clock cycles later, card write enable line C0\_WE\* (shown as C0\_WRCMD\* in Figure 11) is asserted low. After M+1 clock cycles, card write enable line C0\_WE\* is de-asserted low. P+1 clock cycles later, P equal to Recovery\_delay value RECDLY, card output enable line C0\_CE\* is de-asserted.

When a halfword (16-bits) wide write of attribute or common memory is initiated, the value of the BASE address value and the offset address value on system bus address lines SB\_PA are presented on card address lines C0\_A, the data value on system bus data lines SB\_DATA is byte-swapped before being presented onto card data lines C0\_D, and card enable line C0\_CE\* is asserted low. Next, adapter 100 asserts a halfword ACK on system bus line SB\_ACK\*, thereby terminating the write cycle on system bus 55. L+1 clock cycles later, card write enable line C0\_WE\* (shown as C0\_WRCMD\* in Figure 11) is asserted low. After M+1 clock cycles card, write enable line C0\_WE\* is de-asserted. Finally, P+1 clock cycles later, card enable line C0\_CE\* is de-asserted.

The sequence of events required for initiating a word sized write of Attribute/Memory is similar to that of a halfword write of PC card 110. The difference being that adapter 100 asserts a halfword ACK terminating the system bus write cycle, thereby informing host computer 10 that sizing is required to complete the word-size write access. Computer 10 responds by initiating a write of the second halfword of data over system bus 55.

Referring to the timing diagram of Figure 12, adapter 100 also supports data write accesses to attribute or common memory of PC card 110 using the WAIT feature. When a write access is initiated at PC card 110 which utilize card wait line C0\_WAIT\*, the BASE address value and the offset address value on system bus lines SB\_PA are presented on card address lines C0\_A, the data value on system bus data lines SB\_DATA is driven onto card data lines C0\_D, and card enable signal C0\_CE\* is asserted low. Adapter 100 then sends an appropriate ACK, i.e., byte ACK for byte write and halfword ACK for halfword or word

\*Signal is active low.

\*\*Signal is active low.

write, thereby terminating the system bus write cycle.

L+1 clock cycles later, card enable line C0\_WE\* (shown as C0\_WRCMD\* in Figure 12) is asserted low. M+N+2 clock cycles later, card wait line C0\_WAIT\* is sampled. If card wait line C0\_WAIT\* is equal to "0", card 110 is requesting a delay in the completion of the memory access. As discussed earlier, the PCMCIA specification permits a maximum wait period of 12 microseconds. When PC card 110 de-asserts card wait line C0\_WAIT\*, adapter 100 de-asserts card write enable line C0\_WE\* (see C0\_WRCMD\*). P+1 clock cycles later, card enable line C0\_CE\* is de-asserted.

In this embodiment, adapter 100 also supports non-WAIT I/O write accesses of PC card 110 with byte sizing, as illustrated by the timing diagram of Figure 13. A byte I/O write access of PC card 110 is similar to that of a byte write of attribute or common memory with the exception that a card I/O write line C0\_IOWR\* (shown as C0\_WRCMD\* in Figure 13) is asserted instead of card write enable line C0\_WE\*. Similarly, a half I/O write accesses of PC card 110 begin as in the halfword write of attribute or common memory with the exception that card I/O write line C0\_IOWR\* (see C0\_WRCMD\*) is asserted instead of card write enable line C0\_WE\*.

As discussed above, PC card 110 is configured for I/O type operations by loading the appropriate Card Information Structure (CIS) into optional Configuration Registers located at the base of the PCMCIA common address space. The I/O access protocol is similar to common memory access protocol except that card I/O lines C0\_IORD\* (shown as C0\_RDCMD\* in Figure 9) and C0\_IOWR\* (see Figure 13) are used for handshaking instead of card enable lines C0\_OE\* and C0\_WE\*, respectively (shown as C0\_RDCMD\* and C0\_WRCMD\* in Figures 9, 11, respectively).

Referring again to Figure 13, PC card 110 asserts card line IOIS16\* low (not shown) to indicate that card 110 is also capable of executing a 16 bit wide write. In response, adapter 100 asserts card enable line C0\_CE1\* low so that both bytes of data presented on card data lines C0\_D are written into PC card 110.

Conversely, if PC card 110 does not assert line IOIS16\* (not shown) low during the I/O write access, i.e., PC card 110 is not capable of performing a 16 bit I/O write, only card enable line C0\_CE1\* is asserted low so that only the even byte presented on card data lines C0\_D from system bus data lines SB\_DATA is written into PC card 110. Adapter 100 then completes the halfword I/O write cycle by executing one more I/O byte write to PC card 110 as described above. This

second byte I/O write access differs from the first byte write in that card address line C0\_A[0] is set to "1" and the odd byte value from system bus data lines SB\_DATA is presented onto card data lines C0\_D.

Adapter 100 also supports I/O write access of PC card 110 with the WAIT feature. Referring back to Figure 11, the sequence of events for I/O write access with the WAIT feature is similar to that for write access of attribute or common memory with the WAIT feature, with the exception that card I/O write enable line C0\_IOWR\* (shown as C0\_WRCMD\* in Figure 11) is asserted instead of card write enable line C0\_WE\* during an I/O write access. If PC card 110 asserts but fails to de-assert card wait line C0\_WAIT\* within 20 microseconds, the I/O write access is terminated and card 110 generates a status change interrupt (SCINT) to host computer 10 with PC card access time-out (PCTO) bits set in the Interface Status Register, indicating that a WAIT time-out has occurred.

Appendix B is a detailed data sheet for one embodiment of adapter 100 and is incorporated herein. Appendix C are verilog files of this embodiment and is also incorporated herein.

As discussed above, PCMCIA socket 107 can be configured either to operate in attribute/common memory mode or I/O mode depending on the capability of PC card 110. When PCMCIA socket 107 and is configured for attribute/common memory mode, adapter 100 generates a card status change interrupt whenever adapter 100 detects any of the following events:

PC card access time-out  
PC card write protect status change  
PC card ready-busy\* status change  
PC card battery status change  
PC card is inserted or removed Conversely, when PCMCIA socket 107 is configured for I/O mode, adapter 100 generates a card status change interrupt whenever adapter 100 detects the following events:

PC card access time-out

PC card is inserted or removed

PC card generates a status change interrupt

The interrupts generated by adapter 100 provides a variety of functions. For example, when PC card 110 is configured as an I/O card, PC card 110 generates a status change interrupt to host computer 10 by asserting a card status change line STSCHG\* (not shown) whenever a change in card status is detected. Adapter 100 detects card status line STSCHG\* and in turn generates an interrupt over system bus 55 to computer 10. Host computer 10 reads the Pin Replacement Register on (I/O type) PC card 110 to determine the source of the PC card sta-

\*Signal is active low.

\*Signal is active low.

\*Signal is active low.

tus change interrupt. Each source of the card status change interrupt is individually maskable by adapter 100 and is available on system bus interrupt request line SB\_INT[0]. Subsequently, the card status change interrupt is cleared by host computer 10 by writing a "1" to the corresponding status change bit in the Interface Status Register 0.

As discussed above, this embodiment also includes hardware which supports PC card hot-plugging. Referring back to Figure 6, adapter 100 provides control signals to a power switch 105 for applying and removing one of two power sources Vcc, Vpp to and from PC card 110. Such an arrangement enables PC card 110 to be hot-plugged, i.e., safely connected to or disconnected from socket 107 of adapter 110, without powering down host computer 10 by continuously monitoring the presence and absence of PC card 110 with respect to PCMCIA socket 107 in the following manner.

When host computer 10 is first powered up, adapter 100 does not provide power to PCMCIA socket 107. Instead, upon detecting the existence of PC card in socket 107 during the power-up sequence, or detecting a subsequent insertion of PC card 110 after the power-up sequence, a power switching circuit 105 begins to provide power to PC card 110 by turning on the appropriate power MOSFETs of switching circuit 105. Conversely, when adapter 100 is interrupted and informed of the removal of PC card 110, adapter 100 sends the appropriate signal via Card\_0\_Pwr\_Cntl line which causes power switching circuit 105 to turn off the appropriate power MOSFETs, thereby removing power from PCMCIA socket 107.

In some embodiments, PC card 110 is a mass storage or network device, and PROM 106 is configured to boot host computer 100 using boot images stored in or retrieved over a network connection by PC card 110. PROM 106 also contains a separate CIS interpreter for identifying tuples which provide device identification and configuration information for PC cards, e.g., card 110, during booting. The PROM resident CIS interpreter then builds a device information tree with at least one device information node for each PC card, e.g., PC card 110. In addition, PROM 106 contains information defining the capabilities and system resources of adapter 100. For more information on auto-boot process, see U.S. patent application, Serial No. 07/842,007, entitled "METHOD AND APPARATUS FOR BOOTING A COMPUTER SYSTEM", filed February 25, 1992, incorporated herein by reference in its entirety.

In another embodiment, a 5 volt to 12 volt DC-DC converter 107 provides the higher voltage required by some PC cards for operation, thereby further increasing the versatility of adapter 100. As such, after power is provided to card 110, adapter 100 reads the card information structure (CIS) located in the attribute memory space of card 110, to obtain information

about PC card 110, thereby ensuring that PC card 110 is of the type that adapter 100 is able to support. In yet another embodiment, a test port provides internal diagnostics for adapter 100.

5 The PCMCIA specification Version 2.1 does not support direct memory access (DMA) type operations, and hence data transfers between host computer 10 and PC card 110 are essentially programmed I/O type operations. However, should a later version 10 of the PCMCIA specification support DMA, one skilled in the art will be able to add DMA capability to adapter 100 and make the appropriate modifications to software driver 34, enabling host computer 10 to initiate data transfers between host memory 30 and 15 PC card 110 independent of host CPU 20 after an initial setup.

20 While the invention has been described using specific embodiments, other embodiments, alternatives and modifications will be apparent to those skilled in the art without deviating from the scope and 25 spirit of the invention. For example, the PCMCIA interface of the present invention may be implemented in varying proportions of hardware and software. Hence, the above description is merely illustrative and not intended to be limiting. The true scope of the invention is indicated by the following claims.

### Claims

30 1. A PCMCIA interface for providing communications between a user application running on a host computer and a PC card, said interface comprising:

35 a hardware-independent nexus for processing an external PCMCIA access request from said user application and generating a corresponding internal PCMCIA access request;

40 a hardware-dependent driver coupled to said hardware-independent nexus for processing said internal PCMCIA access request and for causing a corresponding system bus signal to be generated on said system bus; and

45 a PCMCIA adapter coupled between said system bus and said PC card for converting said system bus signal into a PC card signal for said PC card.

50 2. The PCMCIA interface of claim 1 wherein said external PCMCIA access request is a PCMCIA card service request and said hardware-independent nexus includes a Card Services provider for processing said PCMCIA card service request.

55 3. The PCMCIA interface of claim 2 wherein said hardware-independent nexus further includes a PCMCIA nexus driver coupled to said Card Services provider for converting said card service re-

quest into said internal PCMCIA access request for said hardware-dependent driver.

4. The PCMCIA interface of claim 3 wherein said hardware-independent nexus further includes an events manager coupled to said PCMCIA nexus driver for providing a communication channel between said PC card and said user application enabling said PC card to generate an unsolicited event report to said user application.

5. The PCMCIA interface of claim 1 wherein said hardware-dependent driver includes an adapter driver for converting said internal PCMCIA access request into a system bus signal for said PC card.

6. The PCMCIA interface of claim 2 wherein said Card Services provider includes an interpreter for parsing an information tuple from said PC card.

7. The PCMCIA interface of claim 1 wherein said host computer is a SPARC based computer system.

8. The PCMCIA interface of claim 1 wherein said system bus is a SPARC based SBus.

9. The PCMCIA interface of claim 1 wherein said host computer is a UNIX based computer system.

10. A method of providing communications between a user application running on a host computer and a PC card coupled to a system bus of said host computer, said method comprising the computer implemented steps of:  
 processing said external PCMCIA access request;  
 generating an internal PCMCIA access request in response to said external PCMCIA access request;  
 processing said internal PCMCIA access request;  
 generating a system bus signal on said system bus in response to said internal PCMCIA access request; and  
 converting said system bus signal into a PC card signal in response to said system bus signal.

11. The method of claim 10 wherein the step of processing said external access request includes the step of providing PCMCIA card services.

12. The method of claim 10 further comprising the computer implemented step of providing a communication channel for said PC card to generate an unsolicited event report to said user applica-

tion.

13. The method of claim 10 further comprising the computer implemented step of parsing an information tuple from said PC card.

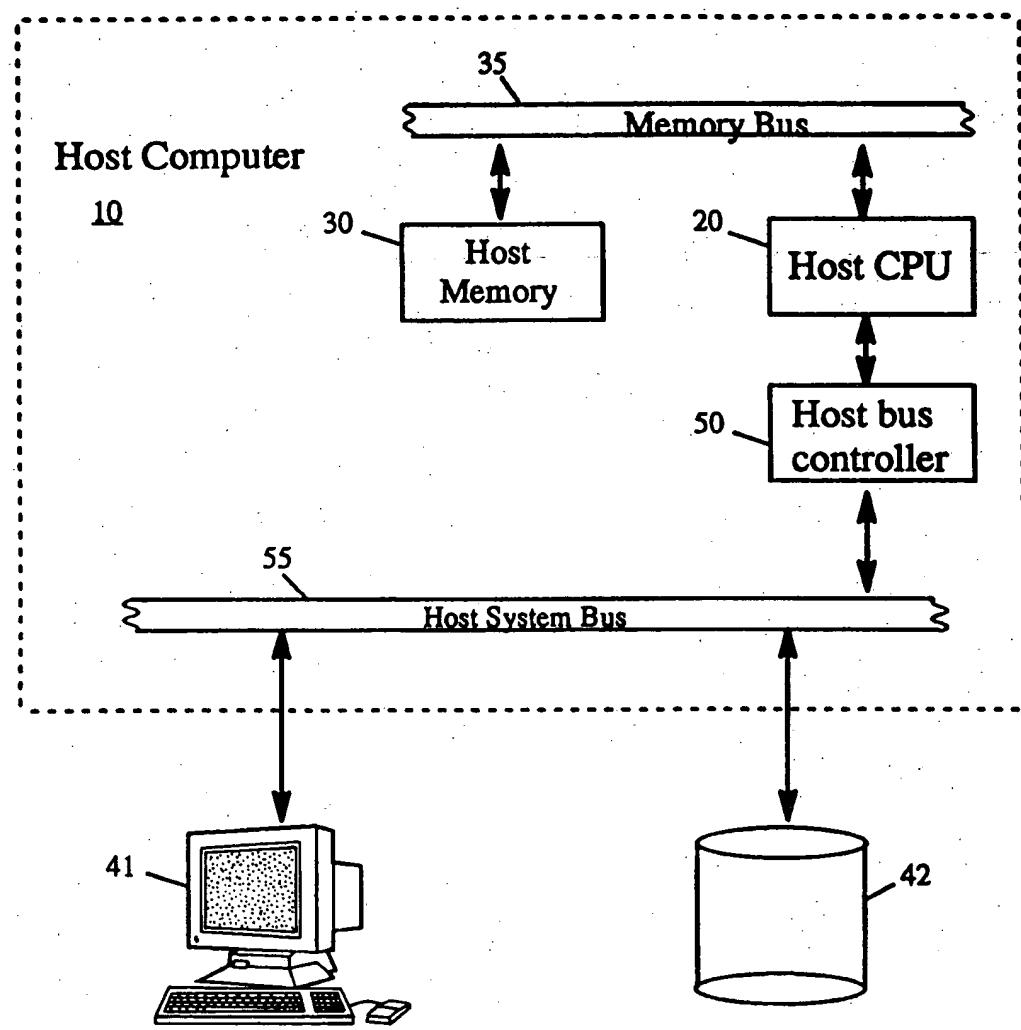
14. The method of claim 10 wherein the step of converting said system bus signal includes the step of converting an SBus signal.

15. A PCMCIA adapter for interfacing between an SBus of a host computer and a PC card, comprising:  
 a PCMCIA socket for accommodating said PC card;  
 a buffer for storing information to be transferred between said SBus and said PCMCIA card; and  
 a core logic for controlling a transfer of said information.

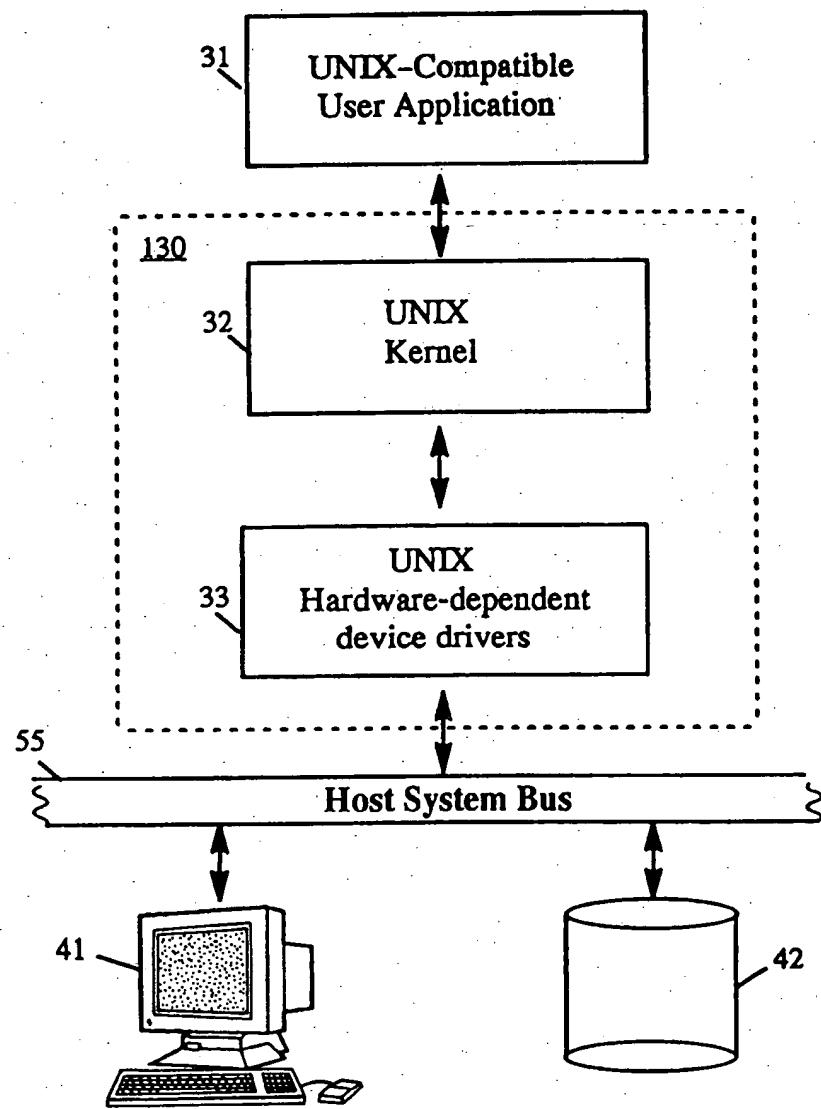
16. The PCMCIA adapter of claim 15 further comprising a switch for applying and removing power between said SBus and said PCMCIA socket.

17. The PCMCIA adapter of claim 15 further comprising a DC-DC voltage supply coupled to said PCMCIA socket.

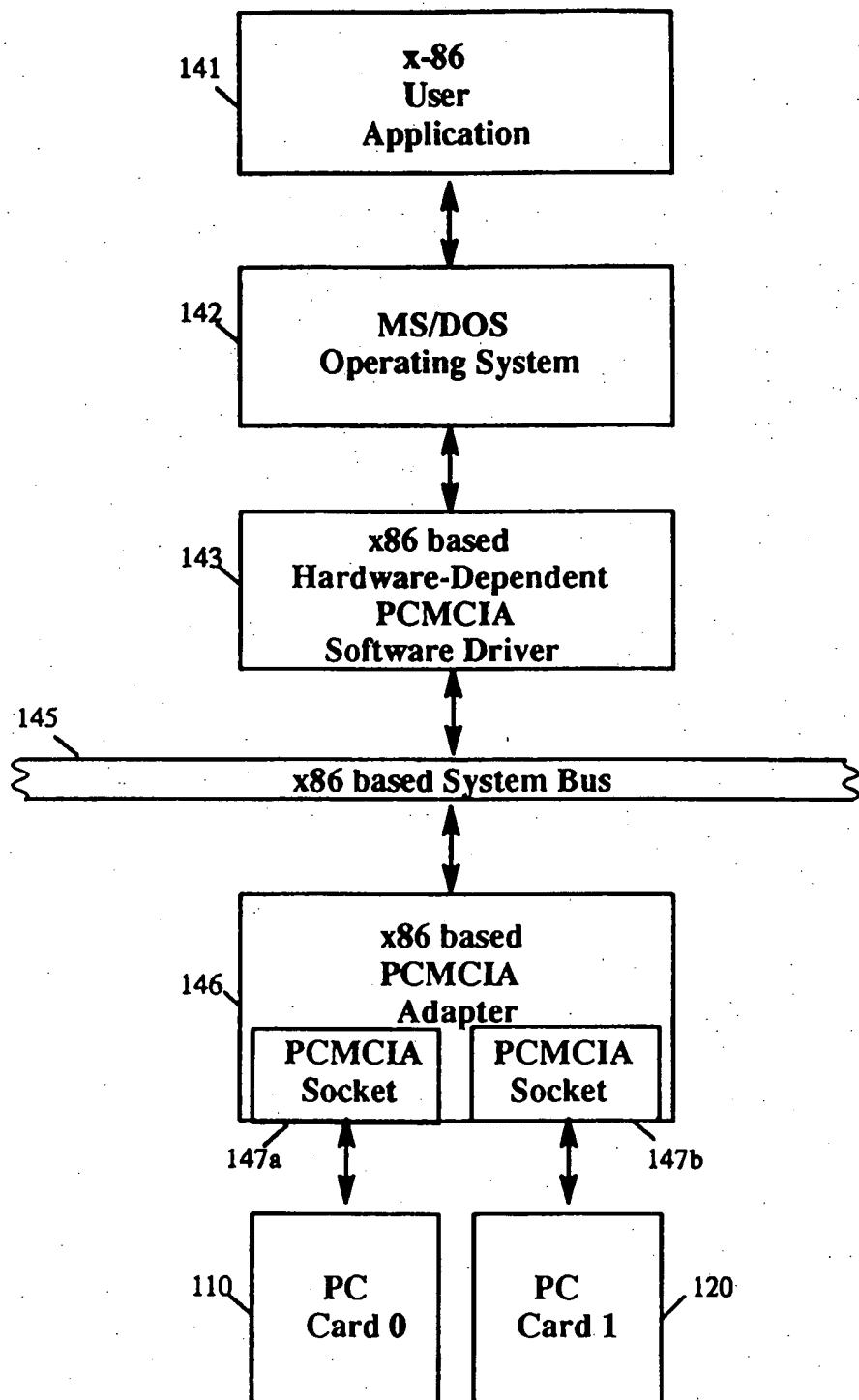
18. The PCMCIA adapter of claim 15 further comprising a boot PROM for booting said host computer with a boot image retrieved from said PC card.



**FIG. IA**  
Prior Art



**FIG. 1B**  
Prior Art



**FIG. 2**  
Prior Art

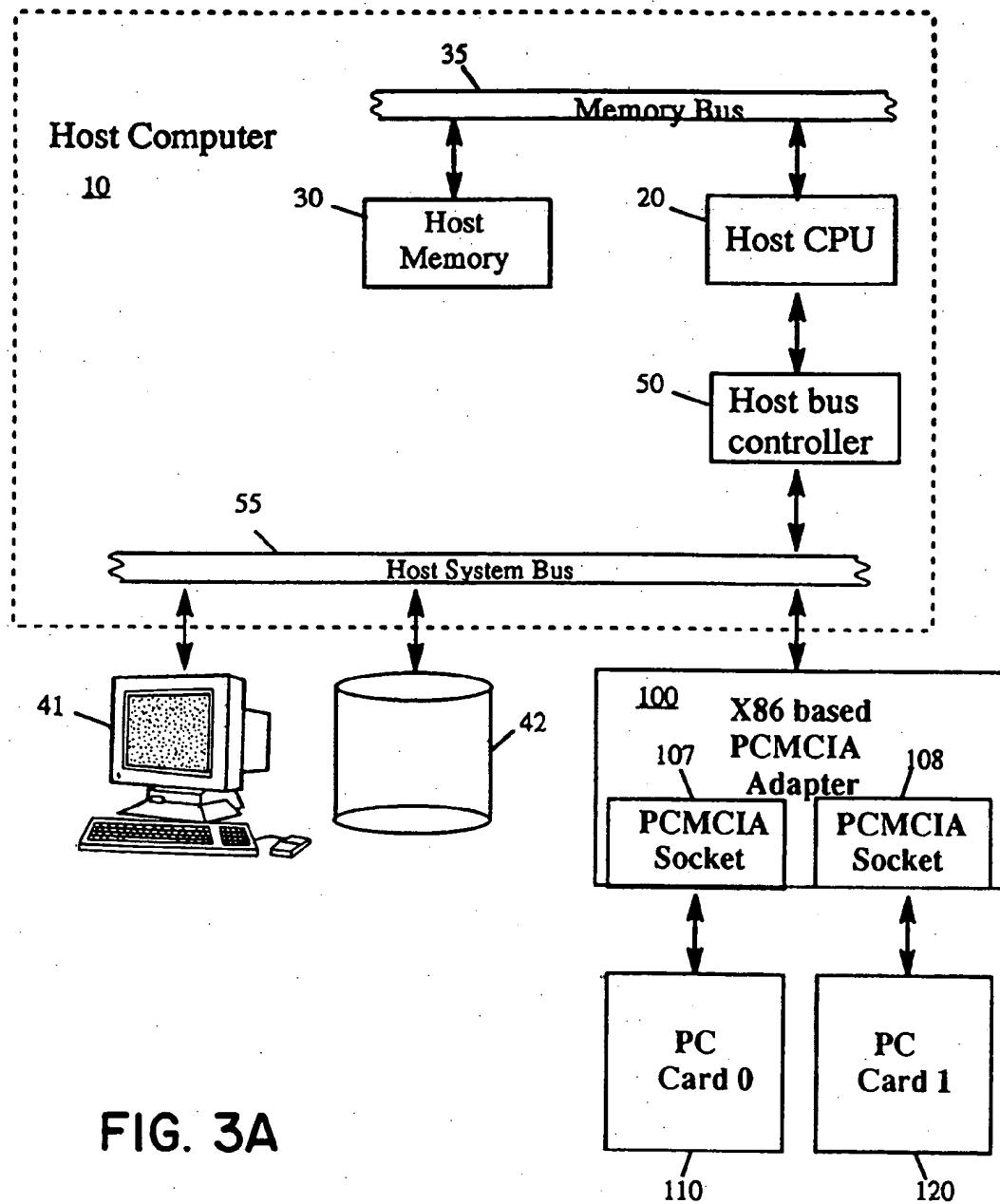


FIG. 3A

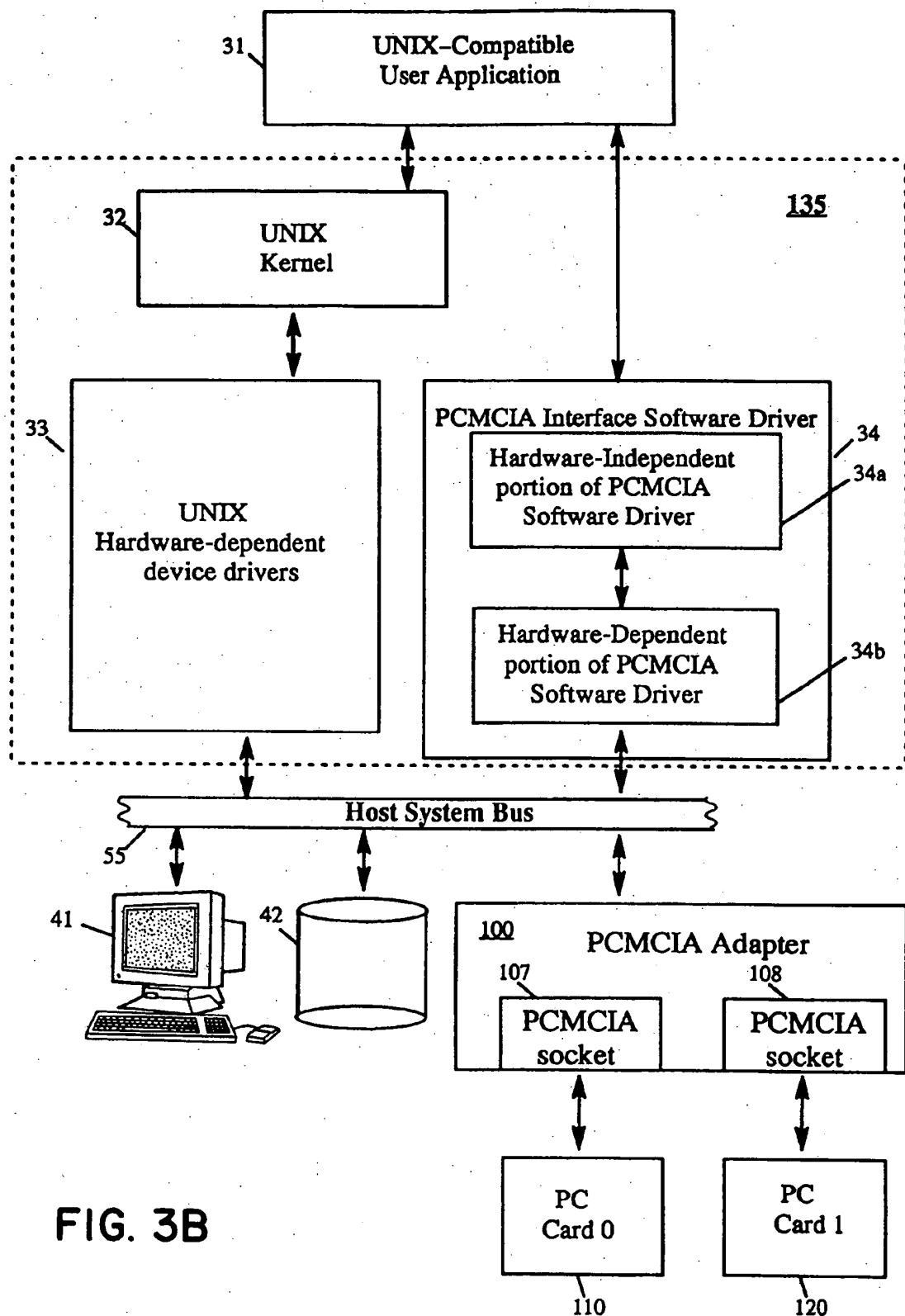


FIG. 3B

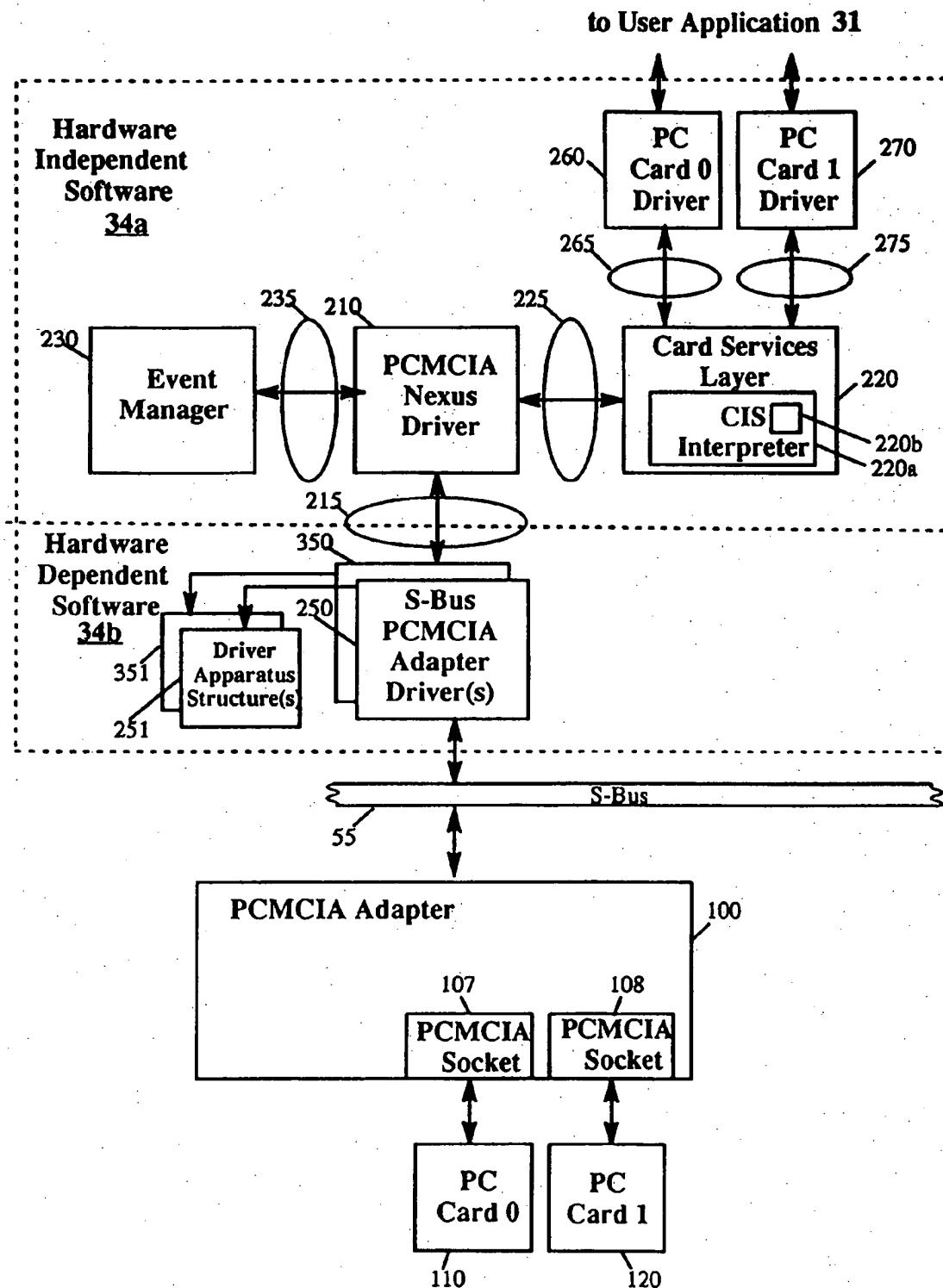


FIG. 4

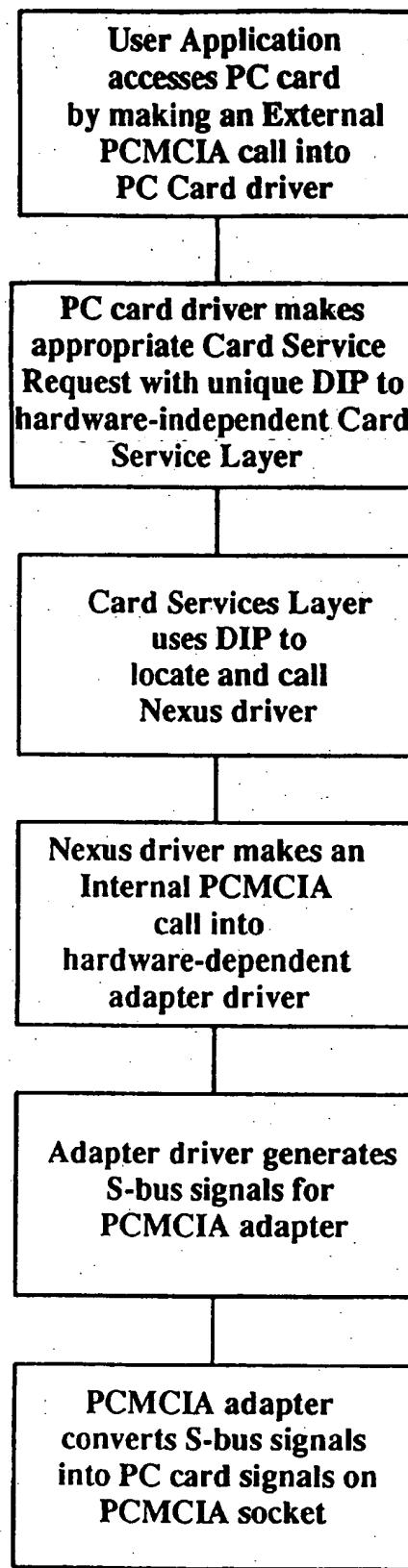


FIG. 5

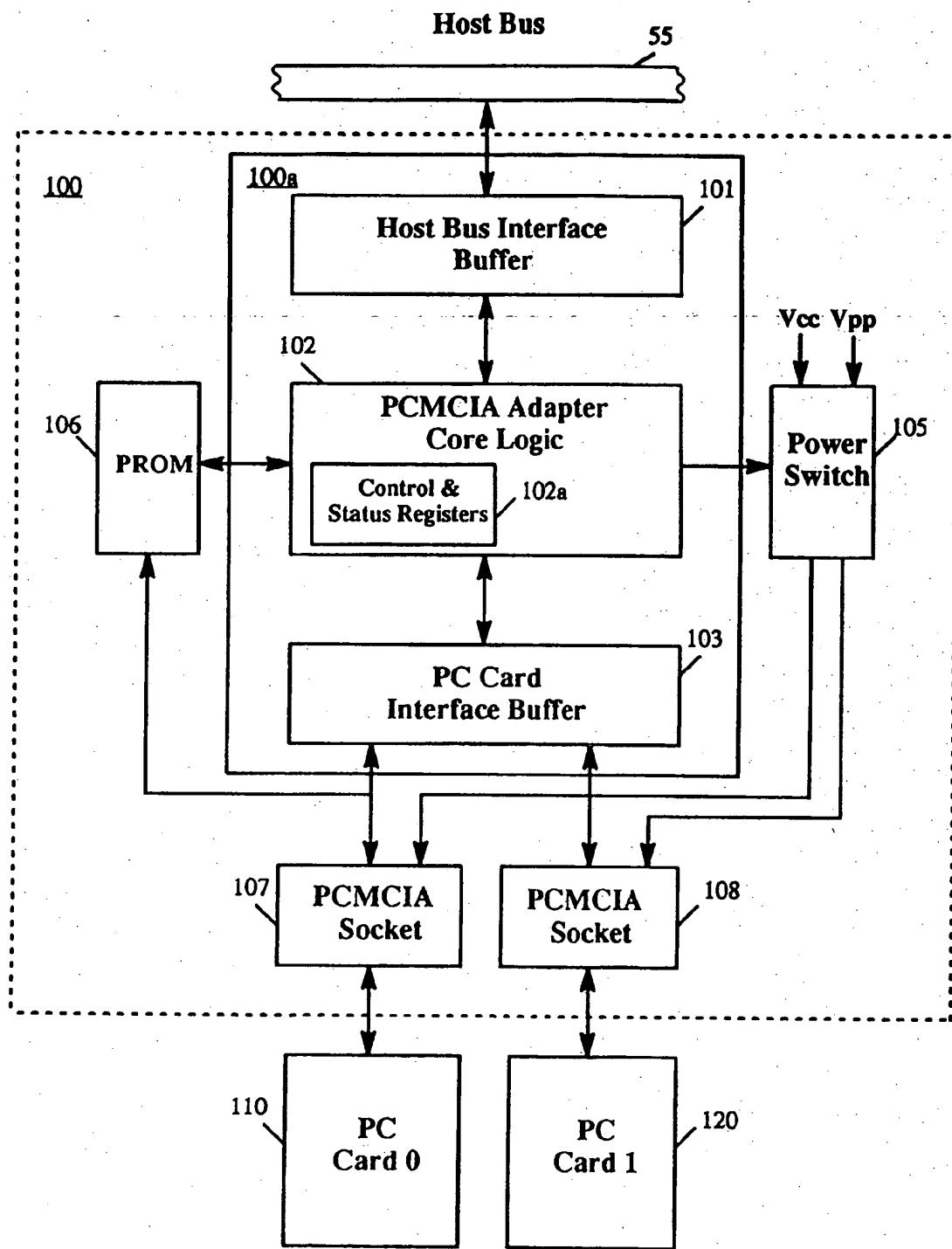


FIG. 6

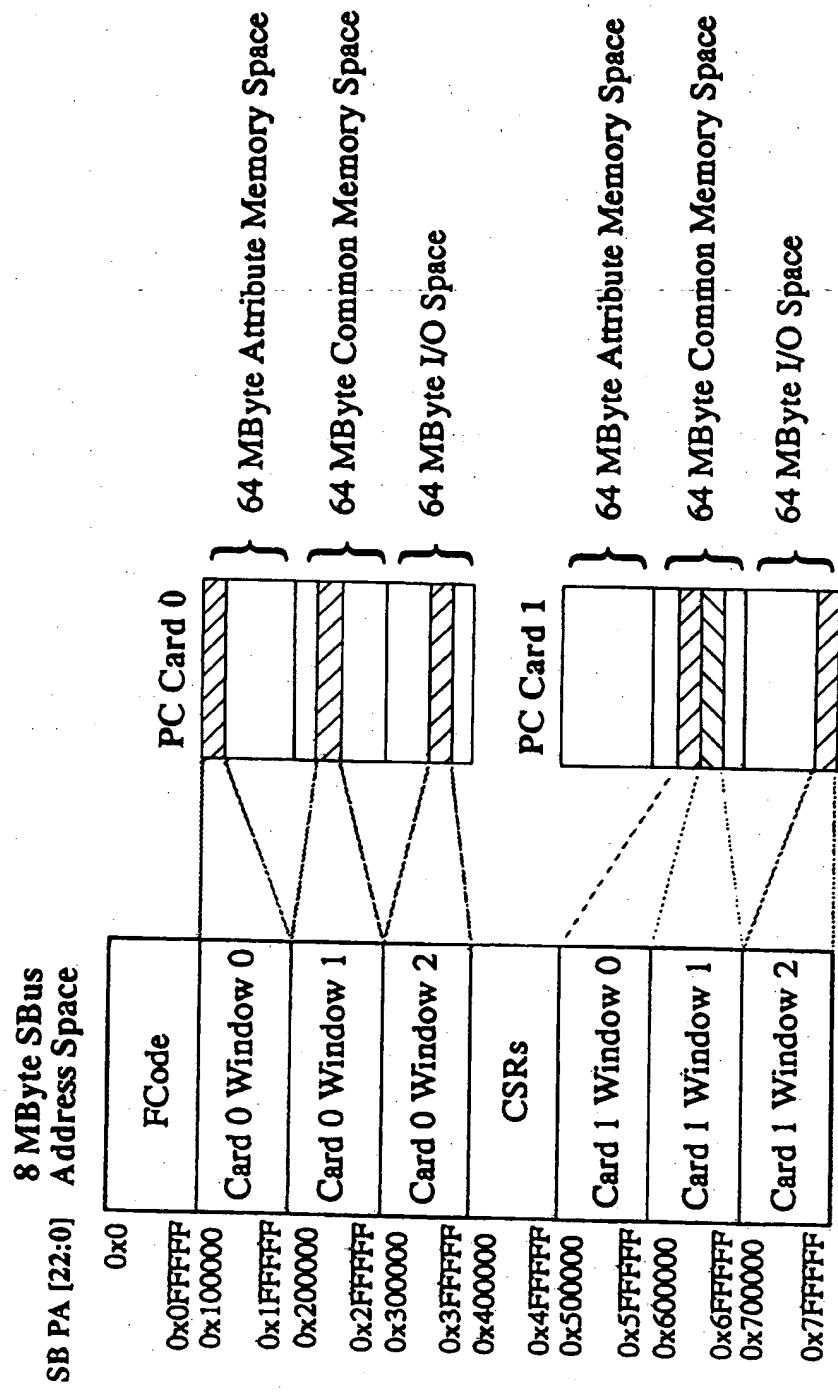
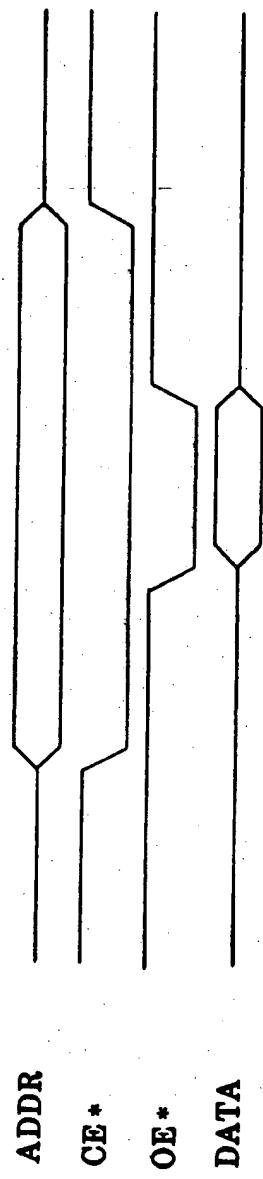
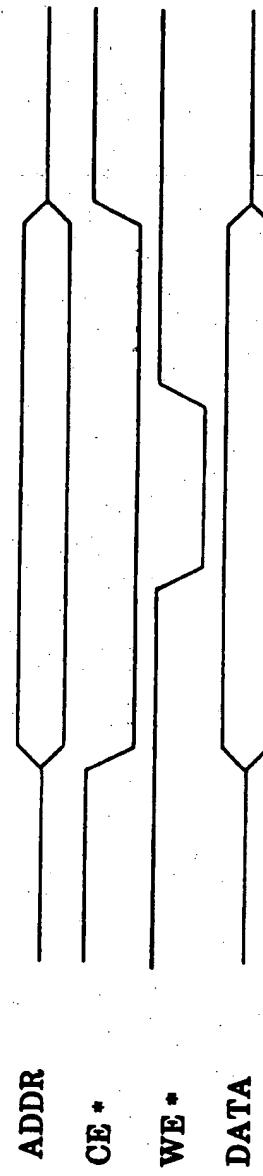


FIG. 7



Basic PC Card Read Access



Basic PC Card Write Access

FIG. 8

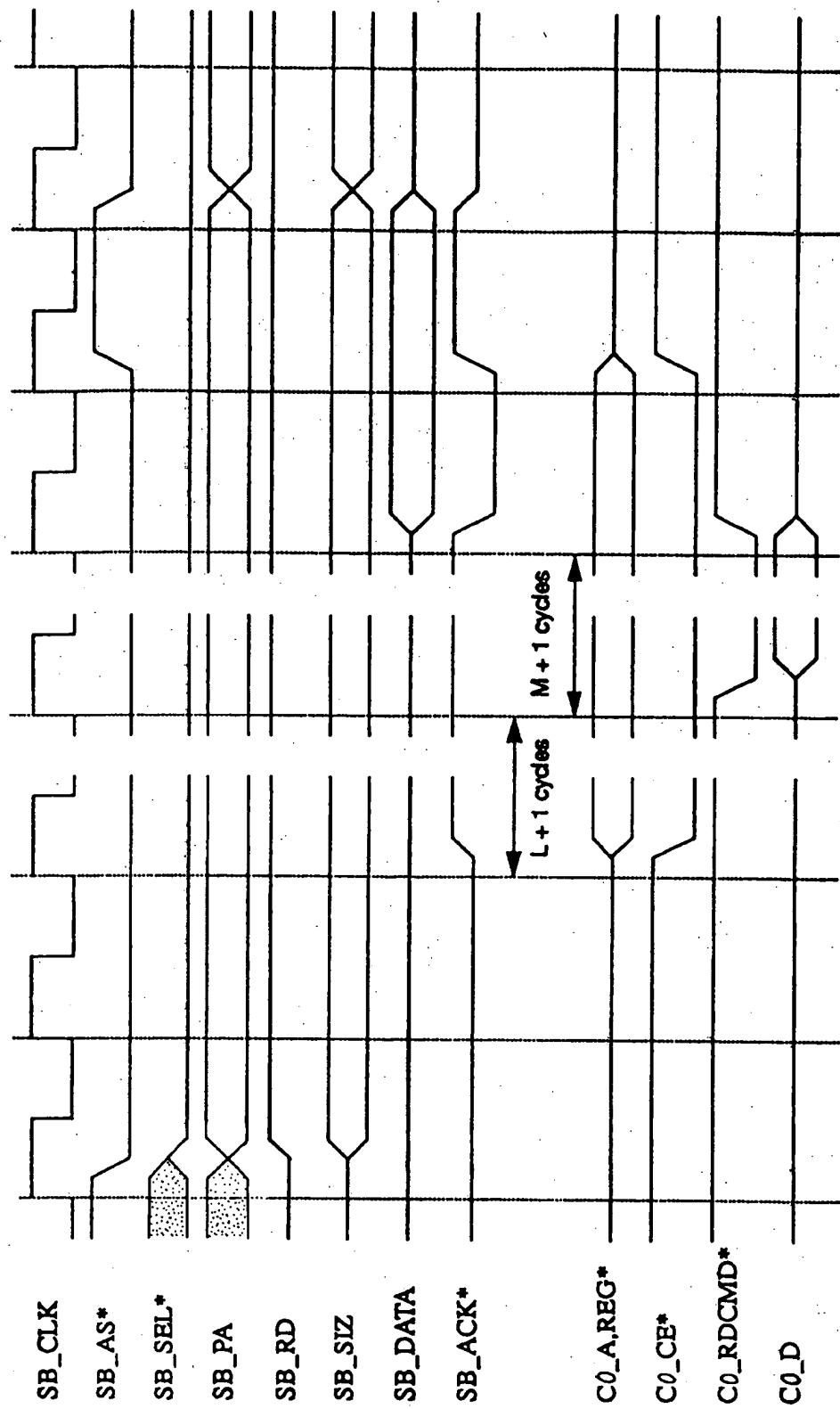


FIG. 9

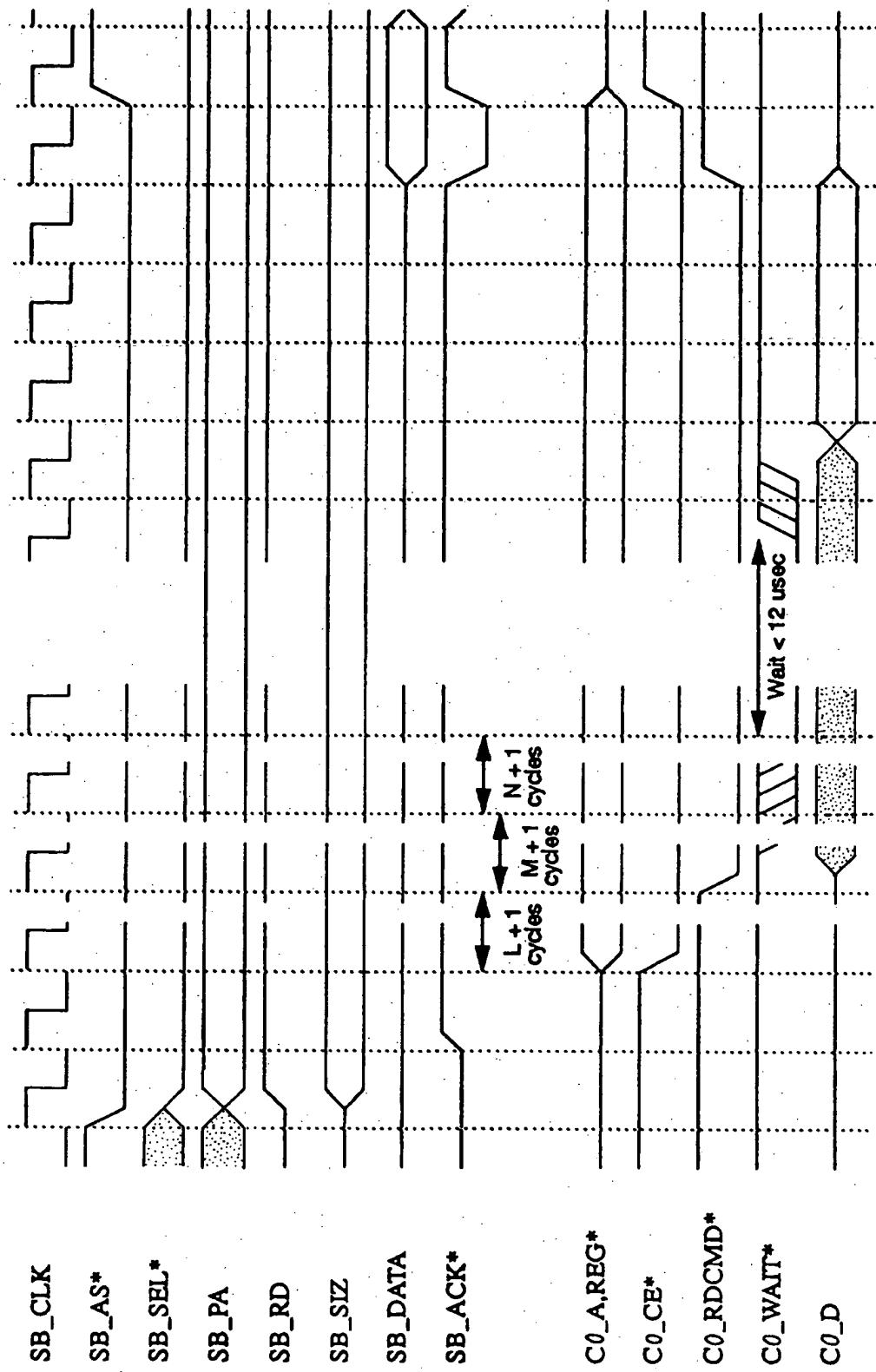


FIG. 10

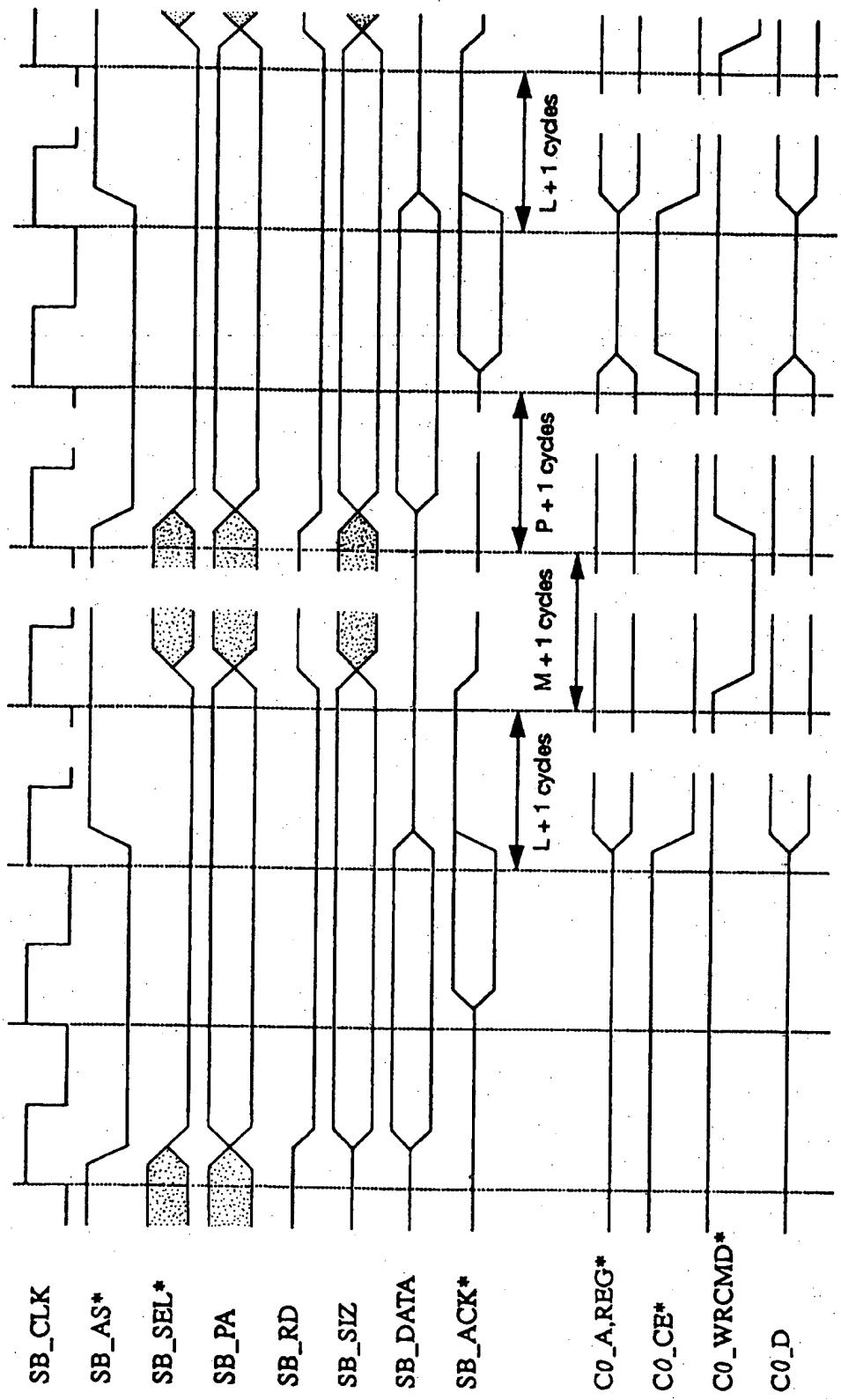


FIG. II

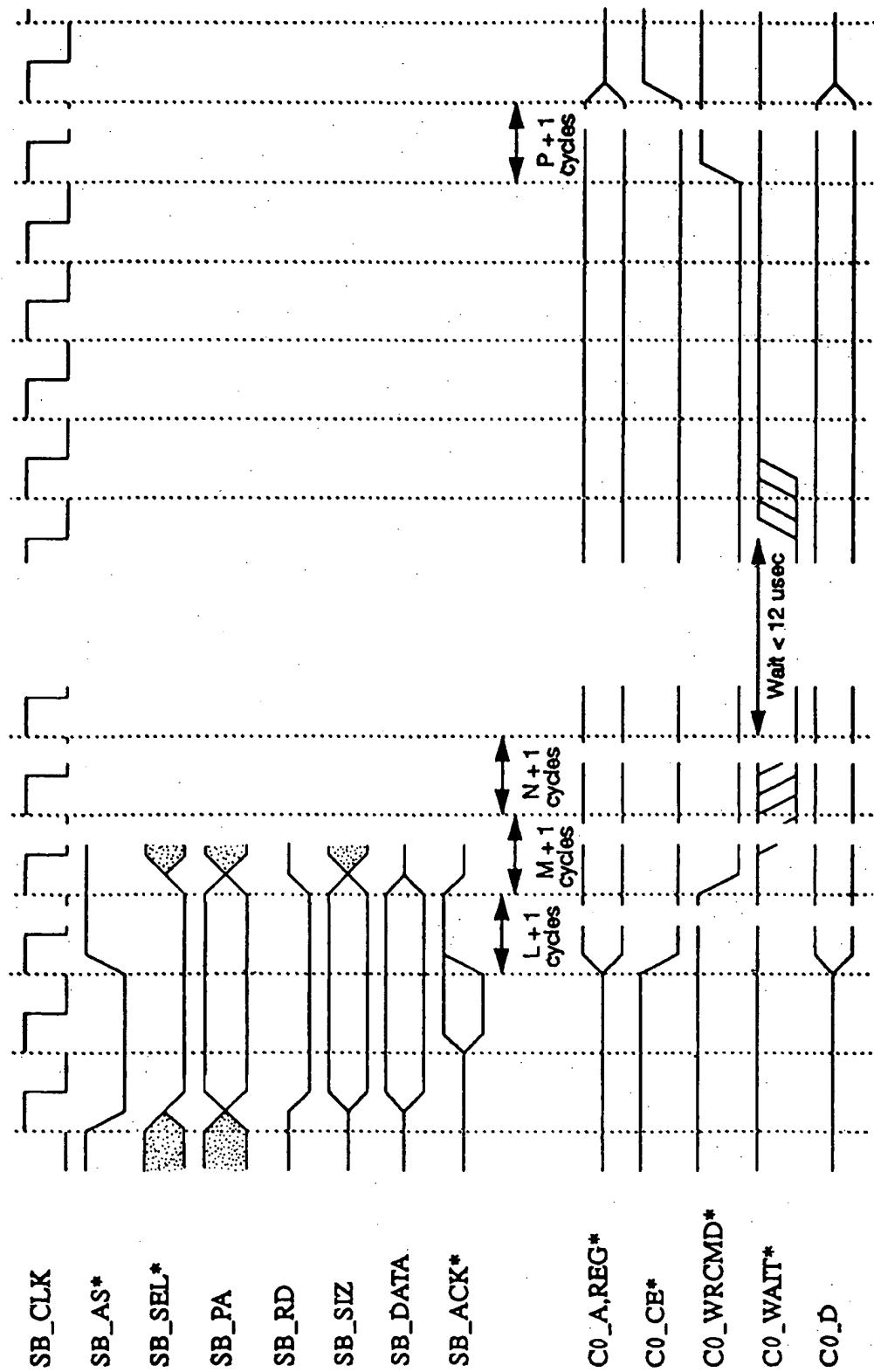
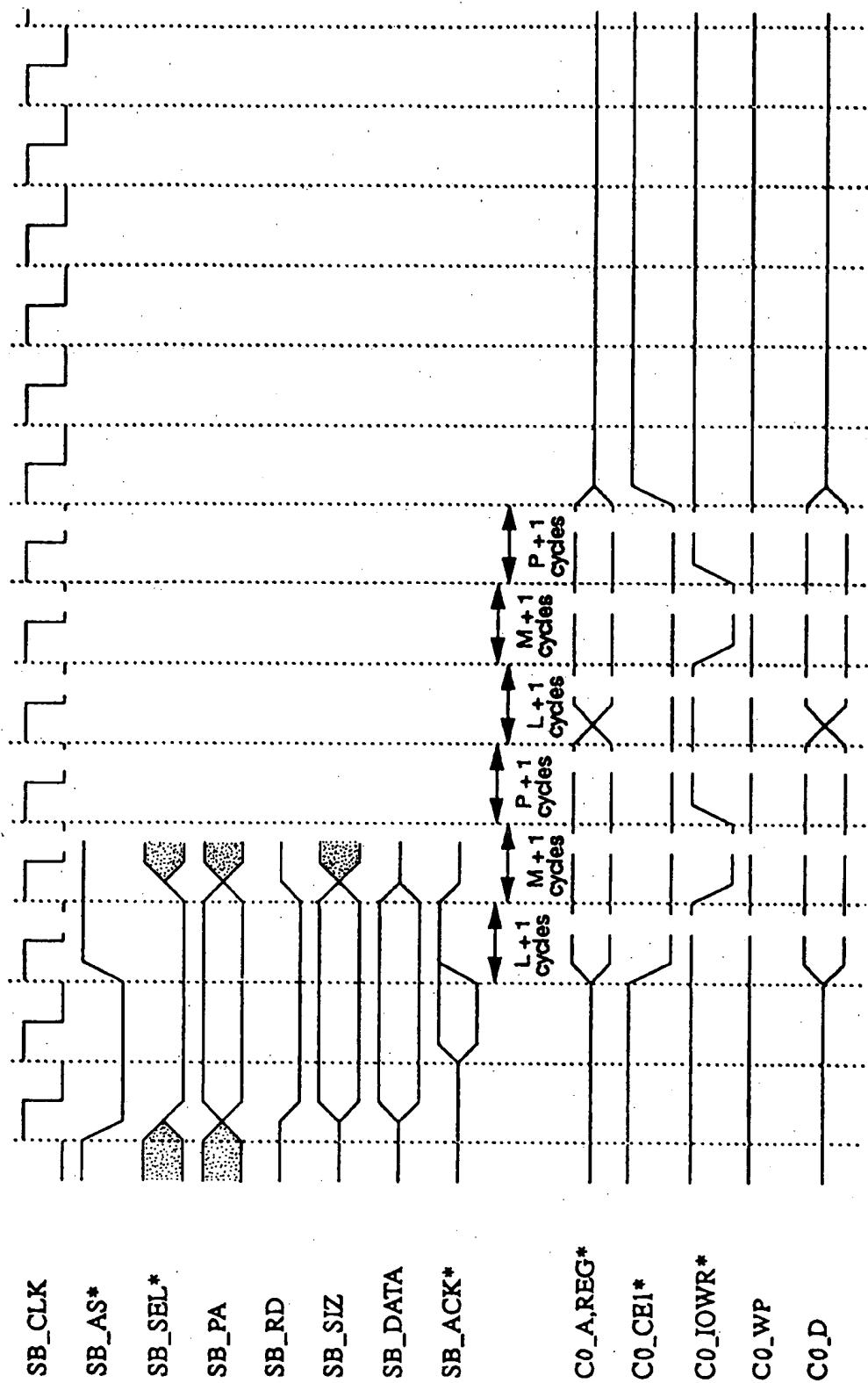


FIG. 12



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